Transportation Literature Search

Prepared by
CTC & Associates LLC

Wisconsin Department of Transportation Research and Communication Services

Open Graded Friction Courses

Prepared for
Wisconsin Highway Research Program
Flexible Pavements Technical Oversight Committee

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Transportation Literature Searches are prepared for WisDOT staff and principal investigators to heighten awareness of completed research in areas of current interest. The citations below are representative, rather than exhaustive, of available studies on the topic. Primary online resources for the literature searches are the Transportation Libraries Catalog (TLCat), the Transportation Research Information Service (TRIS Online), and various academic and scientific databases. Online copies of publications are noted when available. Hard copies of cited literature may be obtained through the WisDOT Library; contact John Cherney at john.cherney@dot.state.wi.us or 608-266-0724.

KEYWORDS

open graded friction course, OGFC, surface, freeze, thaw, benefit, spray, noise, wet weather

CITATIONS

Title: Comparison of thin-lift hot-mix asphalt surface course mixes in New Jersey
Author(s): Thomas Bennert, Frank Fee, Eileen Sheehy, Andris Jumikis, Robert Sauber
Date: 2005
Doc ID/URL: *Transportation Research Record 1929*, 2005: 59-68.
Description: 10 pp.
Contents: The use of thin-lift hot-mix asphalt (HMA) surface course mixes has gained wide acceptance in the United States as a means of improving ride quality and safety. Generally, these materials are classified as having an open-graded and gap-graded aggregate skeleton, nominal aggregate sizes of 12.5 mm or less, and higher than normal asphalt binder contents and are placed in thicknesses of less than 1 in. (25 mm). The use of the thin-lift materials has been found to improve wet-weather driving conditions, reduce traffic noise associated with the tire-pavement interface, and improve ride quality measurements. Typically, thin-lift HMA surface course mixes found in New Jersey consist of open-graded friction courses and Novachip, with a few roadway sections using microsurfacing and stone-mastic asphalt. Each of these material types is evaluated to provide an assessment of their ride quality and safety. These thin-lift materials are compared with in-service dense-graded asphalt mixes and portland cement concrete (PCC). PCC pavements have three different surface conditions: no treatment, transverse tined, and diamond grind. To establish performance comparisons between the different surface courses, noise measurements using the close proximity method, wet-skid resistance, and ride quality data consisting of the ride quality index and international roughness index were used. The performance information, along with current costs associated with the materials and construction, can provide a means of establishing the cost-effectiveness for the use of these surface treatments under specific situational conditions.

Title: Study of laboratory properties of OGFC considering stone-on-stone contact
Author(s): J. V. Merighi, R.M. Fortes
Date: 2005
Doc ID/URL: *24th Annual Southern African Transport Conference, SATC 2005: Transport Challenges for 2010*, July 11-13, 2005: 105-114.
Description: 10 pp.
Contents: In recent years the major performance problem found with dense graded asphalt mixture used in all bus lanes in Sao Paulo City is permanent deformation. The damage is accelerated by the low speed of the buses, which average around 25 km/h, and the high temperatures during eight months of the year. For these reasons, it is common to find premature rutting in these pavements. On the other hand, the literature reports many cases where stone mastic asphalt (SMA) and Open-Graded Friction Course (OGFG) applications were used to minimise rutting and promote

the best tire/pavement contact. The aim of this paper is to present the research conducted to overcome the rutting problem. This research was focused on the laboratory properties of OGFC with regard to stone-on-stone contact. All mixtures and test specimens were compacted with the Marshall apparatus and the volumetric properties for each mixture were determined. Unconfined static creep tests were conducted at 25oC, 40oC and 50oC.

Title: Evaluation of open-graded friction course mixtures containing cellulose fibers and styrene butadiene rubber polymer
Author(s): Hossam F. Hassan, Salim Al-Oraimi, Ramzi Taha
Date: July/August 2005
Doc ID/URL: *Journal of Materials in Civil Engineering*, Vol. 17 (4), July/August 2005: 416-422.
Description: 7 pp.
Contents: Open-graded friction course (OGFC) or porous mixtures consist of an open gradation, mostly of coarse size aggregate with little fines. The benefits of an OGFC mixture are typically increased surface permeability, noise reduction, and enhanced surface friction, especially in wet weather. This paper presents the results of a study investigating four different OGFC mixes containing no additives, cellulose fibers, styrene butadiene rubber (SBR) polymer, and a combination of both fibers and SBR polymer. Mix designs were performed according to the design procedure proposed by the National Center of Asphalt Technology for a range of 4.5-6.5% asphalt content. The mixture containing fibers and SBR polymer was selected as an acceptable mix design with an optimum asphalt content of 6.5%. The moisture susceptibility of the selected mix at optimum asphalt content was evaluated. Results were compared with that for a dense mix. Journal of Materials in Civil Engineering © ASCE.

Title: Influence of pavement surface type on tire/pavement generated noise
Author(s): Thomas Bennert, Doug Hanson, Ali Maher, Nicholas Vitillo
Date: March 2005
Doc ID/URL: *Journal of Testing and Evaluation*, Vol. 33 (2), March 2005: 94-100.
Description: 7 pp.
Contents: Pavement noise evaluations were conducted on 42 pavement surfaces in New Jersey using the Close Proximity Method (CPX) via the NCAT Noise Trailer. The CPX Method is a current ISO Standard that measures sound levels of the tire/pavement interface, thereby providing a method to evaluate solely the influence of pavement surface on traffic noise. The surfaces were comprised of both hot mix asphalt (HMA) and Portland cement concrete (PCC). The HMA surfaces consisted of dense-graded asphalt mixes (DGA), open-graded friction course (OGFC) with and without crumb rubber, stone-mastic asphalt (SMA), NovaChip [registered trademark] , and a microsurfacing slurry mix. The PCC surfaces, pavements and bridge decks, had varying surface treatments consisting of transverse lining, saw-cut tining, diamond grinding, and broom finish. The main focus of the research was to: 1) Evaluate how different pavement surfaces influence the generation of tire/pavement noise, 2) Evaluate the effect of vehicle speed on the tire/pavement generated noise, and 3) Provide guidance as to the repeatability of the CPX method and optimal test distance on the roadway to aid in maximizing testing efficiency. Results of the testing indicated that the asphalt-based surfaces provided the lowest tire/pavement noise levels. Of the HMA surfaces tested, the OGFC mixes modified with crumb rubber provided the lowest noise levels (96.5 dB(A) at 60 mph (96.5 km/h)). However, not only were these mixes modified with crumb rubber, but they also had the finest aggregate gradation. The loudest HMA surface was a 12.5 mm SMA mix (100.5 dB(A) at 60 mph (96.5 km/h)). The PCC surfaces had the highest noise levels. Of all PCC surfaces tested, the transverse tined surface obtained the loudest noise levels (106.1 dB(A) at 60 mph (96.5 km/h)). It was found that if the PCC surface was diamond ground, the noise levels could be comparable, and sometimes lower, than typical HMA pavement surfaces. Typical noise levels of the diamond ground PCC surfaces were approximately 98.7 dB(A) at 60 mph (96.5 km/h). To evaluate the effect of vehicle speed, noise measurements were conducted at 55, 60, and 65 mph (88.5, 96.5, and 104.6 km/h). Test results within this range indicate that on average, the tire/pavement noise increases linearly and at a rate of approximately 0.18 dB(A) for every 1.0 mph (1.6 km/h). The NovaChip [registered trademark] mixes were less susceptible lo the increase in vehicle speed (0.15 dB(A) increase for every 1.0 mph (1.6 km/h) increase), while the PCC broom finish (no treatment) surfaces were affected the greatest by vehicle speed (0.29 dB(A) increase for every 1.0 mph (1.6 km/h) increase). The CPX method was found to be repeatable, with an average standard deviation of approximately 0.13 dB(A), as long as the test distance was greater than 0.2 miles (0.32 km). This is most likely due to the sensitivity of the test method being influenced by the ability to track the identical wheel-path in successive test runs.

Title: Colorado DOT Tire/Pavement Noise Study
Author(s): D.I. Hanson, R.S. James
Date: April 2004
Doc ID/URL: CDOT-DTD-R-2004-5, Colorado Department of Transportation.
http://www.dot.state.co.us/publications/PDFFiles/tirenoise.pdf.
Description: 31 pp.
Contents: In today's society, traffic noise is a serious problem. The term "noise" should not be confused with the term "sound." Noise is the generation of sounds that are unwanted. With respect to traffic, noise would be the generation of sounds that affect the quality of life for persons near roadways. Therefore, traffic noise can be considered an environmental pollution because it lowers the standard of living. Research in Europe and in the United States has indicated that it is possible to build pavement surfaces that will reduce the level of noise generated on roadways. This report provides the results of testing to define the noise levels of selected highway sections in Colorado. It documents pavement noise testing that was conducted on 18 concrete and asphalt projects throughout Colorado. The conclusions from this research are as follows: (1) The quietest hot mix asphalt (HMA) pavement tested was an open-graded friction course (OGFC) surface; (2) The age of the HMA can have a major effect on the noise level of the pavement; and (3) On the portland cement concrete (PCC) pavements that were between 2 and 3 years old, the type of texturing procedure did not seem to make a difference in the noise level measured. It is recommended that the Colorado Department of Transportation consider the construction of a test section or sections that would evaluate the effect of thickness and gradation on the noise characteristics of an OGFC wearing course.

Title: "Quiet Pavements": asphalt pavement mitigate tire/pavement noise
Author(s): P.S. Kandhal
Date: March 2004
Doc ID/URL: *Hot Mix Asphalt Technology*, Vol. 9 (2), March 2004: 22-23, 25-27, 29-31.
Description: 8 pp.
Contents: Traffic noise can cause discomfort or annoyance for people living near highways. Controlling noise usually involves either building highways and homes farther apart or erecting a noise barrier such as a wall. However, noise barriers are expensive, and studies show that they are not completely effective; sound carries over the wall and diffracts around the ends of walls. Another way to lower noise levels is by reducing them at their source. By selecting certain pavements surface types, such as dense-graded hot mix asphalt, stone matrix asphalt or open-graded asphalt friction course, noise levels can be mitigated and the need for expensive barriers eliminated.

Title: Assessment of the Performance of Several Roadway Mixes Under Rain, Snow, and Winter Maintenance Activites
Author(s): G.W. Flintsch
Date: February 2004
Doc ID/URL: Final Report, VTRC 04-CR18, Virginia Transportation Research Council.
http://www.virginiadot.org/vtrc/main/online_reports/pdf/04-cr18.pdf
Description: 30 pp.
Contents: The purpose of this study was to assess the relative functional performance, including skid resistance and splash and spray, of five hot-mix-asphalt (HMA) surfaces and a tinned portland cement concrete highway surface during controlled wet and wintry weather events. The study compared the way that these surfaces respond to various deicing and anti-icing snow removal and ice control techniques under artificial wintry conditions. In addition, the splash and spray characteristics of the surfaces during and immediately after rain were also evaluated. The study focused on the surfaces placed within the all-weather testing area at the Virginia Smart Road. The winter maintenance techniques tested include the application of sodium chloride (salt) in granular, pre-wetted, and liquid forms. The snow removal and ice control measures that were used followed the recommendation of the Federal Highway Administration Project T&E 28 and variations thereof. The experiments to compare the splash and spray characteristics of the mixes were conducted using artificial rain. The study defined and tested a methodology for testing winter maintenance operations under controlled, artificial wintry events. The winter maintenance test results were inconclusive, as the various maintenance treatments were unable to significantly improve the functional condition of the road. Under the temperature and precipitation conditions encountered, there were no significant differences in the performance of the different surface mixes tested. However, conditions encountered did not correspond to conditions normally encountered with natural snow. The researcher concluded that at temperatures at and just below freezing, artificial snow might not be appropriate for evaluating the effectiveness of winter maintenance chemicals. Studies that depend upon imitating the on-road attributes of natural snow, such as testing effectiveness of winter maintenance chemicals, should adhere to the ideal temperature-humidity guidelines for the snowmaking equipment. The open-graded friction course appears to have enhanced spray and splash performance when compared with the dense HMA surface mixes; however, a more objective measure of splash and spray

characteristics of the surfaces is needed to quantify the beneficial effect of this type of mix. No visual difference in performance was observed among the other mixes.

Title: Evaluation of Open-Graded Friction Course Mixturee
Author(s): S.B. Cooper, C. Abadie, L.N. Mohammed
Date: January 2004
Doc ID/URL: TAR No. 04-1TA, Louisiana Transportation Research Center. http://www.ltrc.lsu.edu/pdf/2004/04-1TA.pdf.
Description: 65 pp.
Contents: Open-graded friction course (OGFC) is a porous, gap-graded, predominantly single size aggregate bituminous mixture that contains a high percentage of air voids. The high air void content and the open structure of this mix promote the effective drainage of rainwater, which also minimizes hydroplaning during wet weather. This characteristic also reduces splash and spray behind vehicles and improves wet weather skid resistance. Other purported benefits of this type mix are lower pavement noise and reduced roadway glare during wet weather, which improves the night visibility of pavement markings. This paper documents Louisiana's first use of this type mix since the suspension of OGFC mixes in 1984. Information is included on OGFC mix design and cost.

Title: Laboratory performance testing of open-graded friction course mixtures
Author(s): Donald E. Watson, L. Allen Cooley, Jr., Kathryn Ann Moore, Kevin Williams
Date: 2004
Doc ID/URL: *Transportation Research Record 1891*, 2004: 40-47.
Description: 8 pp.
Contents: Several lab tests were used in this study to evaluate mixture properties. A draindown test, Cantabro stone loss test, a permeability test, and a modified version of AASHTO T-283 were used to evaluate laboratory performance of open-graded friction course (OGFC) mixes. Some of the more pertinent conclusions were as follows. The CoreLok procedure appears to be a more accurate method of determining bulk specific gravity of compacted specimens than the dimensional method. The minimum air voids content for new-generation OGFC mixtures should be 18% on the basis of the dimensional method and 16% on the basis of the CoreLok method. The addition of fiber stabilizers significantly reduced the potential for draindown. Superpave [registered trademark] gyratory compactor (SGC)-compacted samples can be used for the Cantabro stone loss procedure. Unconditioned SGC samples should have stone loss of no more than 20%. If an aging process is used, the maximum amount of stone loss should be limited to 24%. Because there is not a significant difference between unaged and aged sample results, the aging procedure is not necessary. Results from this study show no significant difference in tensile strength when one, three, and five freeze-thaw cycles are used in the moisture-conditioning procedure. Therefore, only one freeze-thaw cycle is needed.

Title: Verification of voids in coarse aggregate testing: Determining stone-on-stone contact of hot-mix asphalt mixtures
Author(s): Donald E. Watson, Eyad Masad, Kathryn Ann Moore, Kevin Williams, L. Allen Cooley, Jr.
Date: 2004
Doc ID/URL: *Transportation Research Record 1891*, 2004: 182-190.
Description: 9 pp.
Contents: During NCHRP Project 9-8, Designing Stone Matrix Asphalt Mixtures, the voids in coarse aggregate (VCA) concept was selected as the preferred method to determine whether stone-on-stone contact existed in stone matrix mixtures. It is believed that stone-on-stone contact is important for open-graded friction course (OGFC) mixes to minimize the potential for rutting. Therefore, the same VCA requirements were adopted for OGFC mixes as had been developed for stone matrix asphalt mixtures. The objective of this study was to verify the VCA concept for defining stone-on-stone contact within OGFC mixtures by using digital imaging techniques such as analyzing particle contacts and the air voids size distribution. The effect of aggregate breakdown on stone-on-stone contact by the VCA method was also evaluated. The following conclusions are based on the information presented in this study. (a) A general guideline for determining the critical breakpoint sieve would be to select the finest sieve for which there is at least 10% of the total aggregate retained. This sieve size also should differentiate between the aggregate skeleton and filler particles. (b) Digital imaging provides a scientific method for identifying when stone-on-stone contact exists and supports the VCA. An advantage of digital imaging is that it can quantify the number of contacts between aggregate particles.

Title: Effect of HMA design properties on pavement surface friction
Author(s): G.W. Flintsch, I.L. Al-Qadi, K.X. McGhee, R. Davis
Date: 2003
Doc ID/URL: Proceedings of the Conference on Maintenance and Rehabilitation of Pavements and Technological Control
Description: 10 pp.
Contents: This paper discusses an investigation conducted to evaluate the frictional properties of seven wearing surfaces used at the Virginia Smart Road. Variations in the International Friction Index (IFI) measurements due to hot-mix asphalt (HMA) design characteristics and testing conditions (tire, test vehicle speed, and grade) were analyzed. The mixtures studied were five different SuperPave mixtures, a stone mastic asphalt (SMA), and an open-graded friction course (OGFC). Surface characteristics were periodically monitored using a locked-wheel trailer, a British Portable Tester, and laser texture measuring devices. HMA properties were measured from both field cores and lab compacted samples. The effect of specific mixture properties on the International Friction Index was studied, including voids in the mineral aggregate, total voids in the mixture, percentage passing the number 200 sieve, and binder type and content.

Title: Georgia Department of Transportation's Progress in Open-Graded Friction Course Development
Author(s): Georgia Department of Transportation (corporate author)
Date: 2003
Doc ID/URL: http://www.dot.state.ga.us/dot/construction/materials-research/b-admin/research/onlinereports/r-OGFC.pdf. Edited version of paper of same title in *Transportation Research Record 1616*.
Description: 9 pp.
Contents: In order to improve the safety of motorists on Georgia highways, the Georgia Department of Transportation (GDOT) has continued to use the most advanced and effective pavements available, including the open-graded friction course (OGFC). Since OGFC was conceived in the 1950's and 1960's, GDOT has used this mix as a thin porous wearing layer, primarily on interstate highways. In the past, GDOT encountered problems with OGFC use, including asphalt cement (AC) draindown, rapid oxidation, raveling, and stripping of underlying layers. Consequently, GDOT placed a moratorium on OGFC use in 1982. Since that time, however, several modifications have been made to improve the performance of OGFC mixes. Hydrated lime is added as an antistripping agent to OGFC and to all other mixes used on the Georgia state route system, including dense-graded mixes which underlie OGFC. Fibers are added to eliminate AC draindown. Polymer-modified AC is added to improve the durability of the pavement by reducing problems associated with premature oxidation and raveling. Production temperatures are increased to more thoroughly dry aggregate components and thus improve AC adhesion. Finally, coarser gradations and thicker layers are used to improve permeability. With the modifications made to OGFC in recent years, significant improvements in mix performance have already been noted. Agencies which have used this mix in the past and experienced problems similar to those experienced by GDOT should consider the possibility of using modified OGFC on high-volume traffic facilities.

Title: Refinement of New-Generation Open-Graded Friction Course Mix Design
Author(s): Donald E. Watson, Kathryn Ann Moore, Kevin Williams, L. Allen Cooley, Jr.
Date: 2003
Doc ID/URL: *Transportation Research Record 1832*, 2003: 78-85.
Description: 8 pp.
Contents: Open-graded friction course (OGFC) has been used in the United States for more than 50 years. In 2000, National Center for Asphalt Technology (NCAT) research led to a recommended mix design procedure for a new-generation OGFC, but the work involved only one aggregate source. Therefore, NCAT is in the process of refining this design procedure to ensure that it is applicable to other aggregate types used in surface mixes throughout the United States. The objectives of NCAT's current research are to refine and field validate the new-generation OGFC mix design procedure. This work has led to several experiments. Several objectives have been identified that need to be addressed. Superpave [registered trademark] technology and use of the Superpave gyratory compactor (SGC) need to be incorporated into the mix design procedure. The Cantabro test for durability and resistance to stone loss needs to be adapted to SGC-prepared specimens and performance parameters established. The asphalt draindown test (AASHTO T 305-97), which was developed for stone-matrix asphalt mixtures, also needs to be evaluated for applicability to OGFC mixtures. In addition, a method for effectively evaluating air void criteria needs to be investigated. On the basis of the research conducted in this study, 50 gyrations of the SGC was selected as the design compactive effort during mix design. Also, the use of SGC-prepared samples during the Cantabro test appears to be a reasonable alternative to use of Marshall-compacted samples.

Title: Runoff control in porous pavements
Author(s): Vittorio Ranieri
Date: 2002
Doc ID/URL: *Transportation Research Record 1789*, 2002: 46-55.
Description: 10 pp.
Contents: A runoff model from porous pavements is presented that links the hydraulic conductivity (k_p) of porous pavement with the geometric characteristics of the road section and rainfall intensity (I). The theoretical model has been tested in the laboratory with an original device that simulates rainfall on porous pavement and, at the same time, measures the depth of water over the impervious layer during the seepage motion. Based on the experimental data, a useful chart for porous pavement design is also presented. For every inclination (i) of the impervious layer, the graph provides the value of the nondimensional ratio H_{max}/L between the maximum depth (H_{max}) of the water table over the impervious layer and the length (L) of the seepage path, in the function of the nondimensional ratio 4I/k between rainfall intensity (I) and permeability (k). Data provided with this graph could improve porous pavement design (e.g., to assess the minimum thickness of an open-graded friction course needed to avoid surface runoff) usually based only on mechanical resistance determinations. If the chart is not used, to ensure the best flow conditions, the relation $i^2 > 4I/k$ should be always verified.

Title: NCAT develops new generation open-graded asphalt friction course
Author(s): n/a
Date: November/December 2001
Doc ID/URL: *Hot Mix Asphalt Technology*, Vol. 6 (6), November 2001: 24-27.
Description: 4 pp.
Contents: Open-graded asphalt friction courses (OGFC) were used on a routine basis starting in the early 1970s in western states, primarily because they performed much like their predecessor, chip seal, but without its problems like loose gravel. Because it drains well, OGFC was found to reduce splash and glare from wet pavement. It also has a higher-friction surface, so it helps cut skidding and wet-weather accidents. Hydroplaning is also virtually eliminated by OGFC's porous surface. Stripes and pavement markings are more visible at night and during wet weather because there is no standing water, and OGFC reduces noise generated by tires rolling over pavement. Despite these advantages, only 18 out of 42 states surveyed in 1998 said they used it, with many states saying they'd discontinued its use because of problems with premature raveling, stripping of the underlying asphalt course, loss of porosity as voids were clogged by sand and other intrusions and difficulty in plowing, salting and sanding for snow and ice control. The National Center for Asphalt Technology determined a need for specifications and designs for a new generation of OGFC. The prime features are: using very stiff binders of either cellulose or mineral fiber; testing the loose mix for drainage; setting minimum percentages for air voids at 18% and evaluating the mix for resistance to freeze/thaw and abrasion.

Title: Effect of Asphalt Cement Deficiency on Open-Graded Friction Courses
Author(s): M.B. Chopra, R. Andre
Date: May, 2000
Doc ID/URL: Final Report, FM No. 403703, Florida DOT.
http://ntl.bts.gov/lib/17000/17100/17106/PB2000108108.pdf.
Description: 150 pp.
Contents: Raveling is a very common and visible form of asphalt concrete degradation that decreases the effective life of open-graded friction courses. This, in turn, reduces their effectiveness for skid resistance and traffic safety. One of the major causes of raveling is an initial asphalt cement (AC) content below design value (AC deficiency or lean mix). This research project studies the effect of AC deficiency on open-graded friction courses in the state of Florida. Two types of open-graded friction course (FC-2 and FC-5) currently in use in Florida are investigated. This is accomplished by searching Florida Department of Transportation road construction databases for original AC content information for selected Florida highways and then conducting laboratory testing on pavement cores obtained from these roads. Several graphs are generated using the data obtained and conclusions are drawn.

Title: Design, Construction, and Performance of New-Generation Open-Graded Friction Courses
Author(s): R.B. Mallick, P.S. Kandhal, L.A. Cooley, D.E. Watson
Date: April 2000
Doc ID/URL: NCAT Report 00-01, Auburn, Ala.: NCAT, 2000.
http://www.eng.auburn.edu/center/ncat/reports/rep00-01.pdf.
Description: 41 pp.
Contents: Open-graded friction course (OGFC) has been used by several state departments of transportation (DOT) since 1950. While many DOTs report good performance, many other states stopped using OGFC due to

unacceptable performance and/or lack of adequate durability. A vast majority of the states reporting good experience use polymer modified asphalt binders and a relatively coarser aggregate gradation compared to the other states reporting unsatisfactory performance. Obviously, there is a need to develop an improved mix design procedure to help the highway agencies in successful use of OGFC. The primary objectives of this study are to evaluate the performance of OGFC in the laboratory with different gradations and types of additives, and recommend a rational mix design procedure for the new-generation OGFC mixes. Additionally, the construction and performance of six OGFC pavements (constructed prior to this study) are discussed. These mixes generally meet the requirements for gradation band and Cantabro abrasion recommended in the new mix design system. Several polymers and fibers were used in OGFC mixes. The mixes were evaluated for draindown, permeability, Cantabro abrasion, rutting, and moisture susceptibility. A tentative mix design system for the coarse new-generation OGFC has been recommended. Based upon the evaluation of six OGFC field pavements, it has also been shown that OGFC mixes meeting the new mix design requirements are constructible and have exhibited good performance.

Title: Performance Survey on Open-Graded Friction Course Mixes
Author(s): G. Huber
Date: 2000
Doc ID/URL: NCHRP Synthesis of Highway Practice No. 284, Washington, D.C.: Transportation Research Board, 2000.
Description: 44 pp.
Contents: This synthesis report will be of interest to construction, maintenance, pavement design, and materials engineers, pavement contractors, and others interested in the use of open-graded friction course (OGFC) mixes. It describes the current state-of-the-practice on the use of OGFC mixes. This includes information regarding design, materials, construction, maintenance, and rehabilitation strategies. Alternative treatments to traditional OGFC are also identified and discussed. Information for the synthesis was collected by surveying U.S. and Canadian transportation agencies and by conducting a literature search to gather further information on North American and European practices. This report of the Transportation Research Board describes the recent performance of North American OGFC and European porous asphalt by identifying and discussing benefits and stress indicators. A new generation of OGFC has evolved in the last five years with changes that have been reported to dramatically improve the performance of OGFCs. Changes include a combination of empirical design adjustments, adoption of innovative technologies, and improved methods of construction. The synthesis describes new material and design methods in use, as well as the applicability of the new generation of open-graded mixtures to North American use.

Title: Evaluation of open-graded friction course mixtures containing cellulose fibers
Author(s): L.A. Cooley, Jr., E.R. Brown, D.E. Watson
Date: 2000
Doc ID/URL: *Transportation Research Record 1723*, 2000: 19-25.
Description: 7 pp.
Contents: Open-graded friction courses (OGFCs) are special-purpose mixes used to improve friction, minimize hydroplaning, reduce splash and spray, improve night visibility, and lower pavement noise levels. OGFCs typically utilize a gap grading for aggregates and a low percentage of filler. The asphalt content for OGFCs is generally slightly higher than that for dense-graded mixes. The combination of uniform grading, low filler, and normal OGFC asphalt content can lead to the draining of asphalt binder from a mix (typically called draindown) during transportation and laydown procedures. States that use OGFC typically utilize fibers to help prevent draindown. Generally, these states have specified mineral fibers over organic fibers because of concern that organic fibers (cellulose) would absorb water and lead to moisture problems in the field. A study was conducted to evaluate the use of cellulose fibers in OGFC mixes. The study entailed both a field phase and a laboratory phase. Field work entailed conducting a visual distress survey of six experimental OGFC pavements placed in Georgia during 1992. These pavements contained six different combinations of binder polymer and additives. Laboratory work entailed preparing OGFC mixes with both cellulose and mineral fibers and performing numerous moisture sensitivity tests. Results indicated that cellulose fibers performed as well as mineral fibers in OGFC mixes.